# EFFECTS OF SPEAKING RATE ON THE TIMING OF SINGLE AND GEMINATE SONORANTS

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**ABSTRACT**

Cypriot Greek single and geminate sonorants (/m, n, l, r/) at normal and fast speaking rate were compared to sonorants in Standard Greek, which has no length distinction. Cypriot singletons and geminates all shortened at fast rate, except for the single [ɾ]. There was no overlap between singletons and geminates either within or across speaking rates. The duration of Greek sonorants was intermediate between the two Cypriot categories. The [ɾ] results show that reported asymmetries on the effects of rate are due to the incompressibility of certain categories and are not imposed by the linguistic system. However, the contrasts a category enters within a system affect this category's values, as manifested in the greater length of the Greek sonorants. Finally, the results show that when duration is the main cue to a categorial distinction, no durational overlap occurs between categories, contrary to what studies on contrastive vowel length suggest.

## 1. INTRODUCTION

Several studies of the effects of speaking rate on segmental timing report that in a given set of categories (which are contrastive within a linguistic system) one member of the set remains largely unaffected by changes of rate (e.g. [6] on VOT, [13] on the /b/ and /w/ transitions). These reported asymmetries could be the result of pressure from the linguistic system to keep contrasting categories apart (e.g. [12]). On the other hand, it has been argued that categories such as short-lag VOT are subject to strict articulatory constraints and thus unlikely to exhibit durational variability under changes of rate [6]. This explanation of the asymmetrical findings is supported by the results of studies on contrastive vowel length, which show that no category remains stable under changes of speaking rate (e.g. [4] for American English, [1] for Thai, [11] for Korean). Studies of contrastive vowel length, however, also show extensive overlap of categories under changes of rate. This finding could be related to the fact that the contrasts investigated do not rely solely or primarily on duration; some also involve quality differences, others are allophonic, while others seem to be disappearing (see [11] for a review).

A contrast that does not present the type of problems discussed above is that of single and geminate sonorants. Sonorants display the relatively "loose" timing of vowels, while the contrast between geminates and singletons relies mainly on duration [8]. A linguistic variety which allows us to examine single and geminate sonorants is Cypriot Greek (henceforth CYG), the dialect of Greek spoken on the island of Cyprus. CYG has lexical (i.e., phonemic) single and geminate sonorants, /m/, /n/, /l/ and /r/, [14]. An advantageous feature of the Cypriot Greek system is that the single /r/ is a tap [ɾ] – a strictly controlled segment [10] – while the geminate is a trill [r] (the contrast is quite similar to that found in Spanish [10]). Thus the effect of speaking rate on the "loosely" timed /m/, /n/ and /l/ can be compared to the effect of rate on a category with stricter timing, [ɾ]; the prediction is that [ɾ] will not be affected by rate to the same extent as the other sonorants. A further advantage of studying the CYG sonorants is that it is possible to compare the Cypriot Greek data with data from Standard Greek (henceforth SG), which has the same sonorants but no length distinction. By comparing the results of the two varieties it is possible to test Manuel's [12] and similar predictions that CYG, which makes a categorial distinction on the basis of duration, imposes stronger constraints on the timing of its sonorants than SG, in which sonorants do not enter a contrast based on duration.

## 2. METHOD

### 2.1. Materials

For CYG, four disyllabic minimal (or near minimal) pairs with a single or geminate intervocalic sonorant and stress on their final syllable were used as test words; they can be seen in Table 1. For SG, only the test words with the intervocalic singleton were used; these words, shown in the leftmost column of Table 1, have the same gloss in CYG and SG. Of the words with geminates, [voˈrra] is homophonous with [voˈra] in SG, while the other three words do not exist in this variety.

For CYG, each test word was embedded in the carrier phrase [ˈipendu ___ ksafniˈka ˈtʃefien] "S/he-said-to-him ___ suddenly and-left"; for SG the carrier phrase was adapted to [tu ˈipe ___ ksafniˈka ˈcefiɟe] "To-him s/he-said ___ suddenly and-left."

| Singletons | | Geminates | |
|---|---|---|---|
| Test word | Gloss | Test word | Gloss |
| [maˈmu] | *nonsense word* | [maˈmmu] | "midwife" |
| [ðaˈni] | "Danes" | [maˈnni] | "crazy" *fem.* |
| [kaˈli] | "good" *fem.* | [kaˈlli] | person's surname, *fem.* |
| [voˈra] | "food" | [voˈrra] | "North" *acc.* |

Table 1. On the left, the SG set of test words and the CYG test words with single intervocalic consonant; on the right, the CYG test words with geminate intervocalic consonant.

### 2.2. Speakers

The materials were elicited from eight speakers, four of each linguistic variety. The Cypriot speakers were two males in their thirties (KR and PP) and two female students of the University of Cyprus (MK and CA) in their twenties. All of them had been

brought up and lived in Nicosia, Cyprus, and spoke what would be called educated "town" Cypriot Greek. The Standard Greek speakers were members of the academic staff of the University of Cyprus, in their thirties; three were female (YA, AR and AA) and one male (TP). They all came from Athens and spoke Standard Greek, although two of them, YA and AA, had lived in Cyprus for four and three years respectively when the recording took place. None of the speakers reported any speech or hearing problems. With the exception of AA (the author), they were naïve as to the purposes of the experiment; KR helped the author choose the CYG test words and carrier phrase but without being told the specific questions addressed in the experiment.

**2.3. Procedure**

The speakers read the sentences from cards. For the Cypriot materials, the sentences were written in the Greek alphabet but following the unofficial orthographic conventions of Cypriot Greek (which is not normally written); according to these conventions, the geminate consonants are spelt with two letters, e.g. καλλη for [ka'lli] (c.f. καλη for [ka'li]). SG materials were written in the Standard Greek orthography (which also uses double letters for historical reasons, although these are not pronounced as geminates).

The speakers produced six repetitions of the test sentences at normal rate and six repetitions at fast rate. For the normal rate, speakers were instructed to speak as they normally would if reading aloud. For the fast rate, they were asked to speed up, as if they had to stop a telephone conversation abruptly. During the recording they were asked to repeat disfluent sentences.

The materials were recorded directly onto disk at a sampling rate of 22,050 Hz, using Kay's Multispeech software on a standard PC equipped with an AWE64 Sound Blaster multimedia card and a SONY ECM-909 stereo microphone. The recording took place in an office in reasonably quiet conditions and is thus mostly noise free.

**2.4. Measurements**

Measurements of the duration of the whole test word and of the intervocalic test sonorant (among other measurements not discussed here) were obtained from waveforms (aided by spectrograms), using Multispeech.

Standard criteria of segmentation were followed for the measurements. In the waveforms in particular, the nasals and /l/ (which were always intervocalic) were measured as the stretches of low amplitude signal between the higher amplitude envelopes of the flanking vowels; /r/ was measured from the end of the last periodic pulse for the preceding vowel to the onset of the first pulse for the following vowel; the voiced fricatives, /ð/ and /v/ were measured from the onset of frication to the onset of periodicity for the following vowel; stops were measured from the last periodic pulse for the preceding vowel to the onset of the release burst (the short VOT was included in the duration of the following vowel).

## 3. RESULTS

Results for Cypriot Greek are based on a series of two-factor within-subjects analyses of variance (ANOVAs) [rate (normal, fast) × gemination (single, geminate) × speaker (KR, PP, MK, CA)]. Speaker was treated as a random factor. The dependent variables were the whole word duration and the duration of the test sonorants. For both measurements analyses were run separately for each consonant type.

**3.1. Assessing speech rate**

It was important to establish at the onset of the investigation that the speakers used two different speech rates during the recording. To this purpose the duration of the whole test word across rates was statistically analyzed (c.f. [6]). As shown in Figure 1, the duration of the test words was substantially reduced at fast rate [for /m/, $F(1,3)=22.25$; for /n/, $F(1,3)=37.64$; for /l/, $F(1,3)=35.69$; for /r/, $F(1,3)=13.35$; $p<0.05$ in all cases]. The differences across rates ranged from 35-72 ms depending on the test word. These differences constitute 15-21% of the test words' durations at normal rate (which ranged from 283 to 352 ms), and are close to or above the established JNDs for such durations ([7], [9]). In short, it appears that the speakers did use two different speech rates during the recording. There was, however, interaction between rate and speaker in the /m/ and /r/ data [for m, $F(3,20)=7.57$; for /r/ $F(3,20)=7.55$; $p<0.001$ in both cases] (these were the only interactions between speaker and the other two factors). *Post-hoc* Scheffé tests showed that in both cases the interaction was due to speaker PP who failed to show a difference in test word duration between the two rates. Thus speaker PP's results for /r/ and /m/ should be treated with some caution.

Finally, it should be noted that the rate differences applied both to words with an intervocalic singleton and to words with an intervocalic geminate; the former were shorter than the latter in the case of /n/ and /l/ [for /n/, $F(1,3)=103.54$; for /l/, $F(1,3)=32.71$; $p<0.01$ in both cases]. In other words, although gemination was a significant factor in two of the four sets of test words, there was no interaction between it and rate.

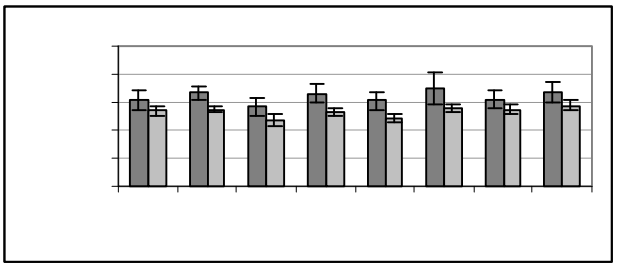

Figure 1. Means and standard deviations of the CYG test words, by intervocalic consonant; dark gray bars show normal rate and light gray bars show fast rate.

**3.2. Single and geminate sonorants in CYG**

The comparisons of the durations of single and geminate CYG sonorants yielded very similar results across consonant type, with only /r/ being different (see below).

First, the factor speaker had a significant effect on the duration of /m/, /n/ and /l/ [for /m/, $F(3,20)=15.61$, $p<0.001$; for /n/, $F(3,20)=9.07$, $p<0.001$; for /l/, $F(3,20)=3.65$, $p<0.03$]. However, with the exception of the /m/ data (discussed in more detail below), speaker did not interact either with gemination or rate. Thus, it appears that the speaker main effect is due primarily to (rather small, as the standard deviations suggest) realizational differences among individual speakers.

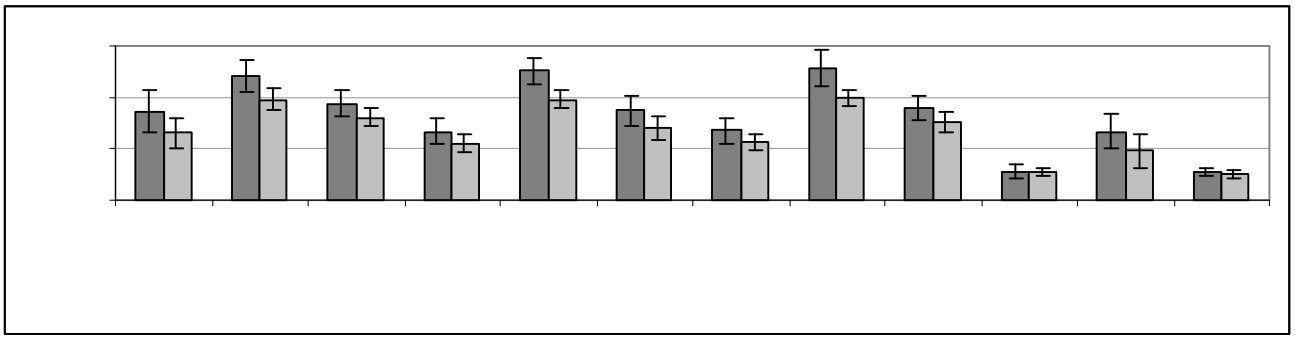

Figure 2. Means and standard deviations of SG sonorants and of CYG single and geminate sonorants; dark gray bars show normal rate and light gray bars show fast rate.

Second, as can be seen in Figure 2, the duration of all sonorants, except /m/, was shorter at fast than at normal rate [for /n/, $F(1,3)=26.06$, $p<0.01$; for /l/, $F(1,3)=119.64$, $p<0.001$; for /r/, $F(1,3)=28.83$, $p<0.01$]. The data for /m/ came very close to the 0.05 level [$F(1,3)=8.04$, $p<0.06$]. But in the case of /m/ there was also interaction between speaker and rate [$F(3,20)=13.22$, $p<0.001$]; Scheffé tests showed this to be due to speaker PP, who failed to make a distinction between his normal and fast rate /m/*s* (a result that tallies with his word duration data). In short, rate affected the realization of all consonants by all speakers, with PP's /m/ data being the only exception.

Third, singletons were clearly shorter than geminates [for /m/, $F(1,3)=19.54$, $p<0.02$; for /n/, $F(1,3)=234.64$, $p<0.001$; for /l/, $F(1,3)=109.13$, $p<0.001$; for /r/, $F(1,3)=202.78$; $p<0.001$]. In fact, the geminates were nearly twice as long as their singleton counterparts though, as can be seen in Table 2, the exact ratio depended on the segment and, to an extent, on the rate of speech.

The only case in which there is no durational difference between a geminate and a singleton is that of /m/ in MK's data; this speaker failed to consistently produce the *nonsense* word /ma'mu/ with a single intervocalic consonant, and as a result there was no difference in the values for her single and geminate /m/*s*. This was the only case of interaction between factors speaker and gemination [$F(3,20)=9.73$, $p<0.001$].

| | CC/C | |
|---|---|---|
| | Normal rate | Fast rate |
| /m/ | 1.40 | 1.48 |
| /n/ | 1.88 | 1.78 |
| /l/ | 1.88 | 1.77 |
| /r/ | 2.39 | 1.78 |

Table 2. Mean CYG geminate/singleton ratios (CC/C) for all speaker, presented separately for normal and fast rate.

In addition to the already mentioned interactions in the /m/ data, there was interaction between rate and gemination in the /r/ data only [$F(1,3)=15.1$, $p<0.03$]. Planned comparisons showed that this interaction was due to the fact that, as expected, the duration of the short /r/, [ɾ], was not affected by rate changes. Geminates, on the other hand, were shortened at fast rate [$F(1,20)=16.12$, $p<0.001$], and there was a difference in duration between single /r/ and geminate /r/ at both normal rate [$F(1,20)=147.67$, $p<0.001$] and fast rate [$F(1,20)=39.3$, $p<0.001$]. In short rate affected both single and geminate sonorants, except /r/, in a similar manner.

Nevertheless, it has often been reported (e.g. [11], [13]) that long segments at fast rate reduce to such an extent that they may acquire values similar to those of short segments at normal rate. In order to establish if this was the case in the present data three-way *between*-subjects ANOVAs (subject × rate × gemination) were run on the data, followed by Scheffé tests (rate × gemination). These tests showed that in no cases were the fast rate geminates not kept distinct from (and longer than) the normal rate singletons ($p<0.005$ in all cases), although it is conceivable that some tokens may have had overlapping values.

### 3.3. Comparing CYG and SG sonorants

For the comparison between Cypriot and Standard Greek, the durations of the test sonorants were subjected to two-way between-subjects ANOVAs [rate (normal, fast) × gemination (CYG single, SG single, CYG geminate)], run separately for each consonant type; the data were pooled across speakers since the issue at hand was to establish, if possible, a general trend across varieties rather than individual speakers.

As can be seen in Figure 2, both CYG and SG sonorants were shorter at fast rate [for /m/, $F(1,138)=62.95$; for /n/, $F(1,138)=92.95$; for /l/, $F(1,138)=84.87$; for /r/, $F(1,138)=18.08$; $p<0.001$ in all cases]. In addition, there was a substantial effect of consonant type [for /m/, $F(1,138)=67.69$; for /n/, $F(1,138)=231.38$; for /l/, $F(1,138)=237.67$; for /r/, $F(1,138)=119.14$; $p<0.001$ in all cases]. Planned comparisons clearly showed that the durations of the SG /m/, /n/ and /l/ were intermediate between the two "extremes" occupied by the CYG singletons and geminates, and significantly different from both [SG/m/ *vs.* CYG/m/, $F(1,138)=15.4$; SG/n/ *vs.* CYG/n/, $F(1,138)=51.6$; SG/l/ *vs.* CYG/l/, $F(1,138)=75.3$; SG/m/ *vs.* CYG/mm/, $F(1,138)=56.6$; SG/n/ *vs.* CYG/nn/, $F(1,138)=195.1$; SG/l/ *vs.* CYG/ll/, $F(1,138)=168.5$; SG/r/ *vs.* CYG/rr/, $F(1,138)=190.9$; $p<0.001$ in all cases]. This effect can be seen clearly in Figure 2, for both fast and normal rate. For the /r/ data, the planned comparisons showed that the SG and CYG single /r/*s* were of the same duration, a result that was expected since the single /r/ is a tap in both Standard and Cypriot Greek. Equally expected was the interaction between rate and consonant type in the /r/ data [$F(1,138)=8.49$, $p<0.001$], which as Scheffé tests

showed was due to the taps being unaffected by rate changes (see also section 3.2.)

Finally, the results suggest that the SG sonorants are not more variable under changes of speaking rate than their CYG counterparts. One indication is the size of the standard deviation; Figure 2 clearly shows that the standard deviations of SG sonorants are comparable to those of CYG single and geminate sonorants. Furthermore, SG sonorants do not shorten more at fast speaking rate than CYG sonorants do, although their temporal reduction would not result in category overlap: as Table 3 shows, the absolute difference between normal and fast renditions was not greater for SG sonorants than for CYG singletons and geminates, nor were the ratios of reduction particularly different.

| | | GR sonorants | CYG singletons | CYG geminates |
|---|---|---|---|---|
| /m/ | ΔT | 13.5 | 20.5 | 23.0 |
| | F/N | 0.85 | 0.76 | 0.80 |
| /n/ | ΔT | 17.6 | 11.6 | 27.8 |
| | F/N | 0.79 | 0.82 | 0.77 |
| /l/ | ΔT | 13.0 | 11.6 | 29.3 |
| | F/N | 0.85 | 0.82 | 0.77 |
| /r/ | ΔT | 1.7 | 1.00 | 18.6 |
| | F/N | 0.93 | 0.96 | 0.72 |

Table 3. Mean differences in duration (ΔT) between fast and normal renditions of each sonorant, and fast/normal ratios (F/N); the values are averaged across speakers.

## 4. DISCUSSION AND CONCLUSION

In summary, the results showed that CYG geminates were longer than CYG singletons, although not as much longer as geminates reported for other languages, such as Italian [3] and Luganda [5]. The durations of single sonorants were also rather shorter than those reported for other languages (e.g. [2] for American English). In SG, which has no length distinction, the sonorants were intermediate in duration between the single and geminate CYG segments, and comparable to those reported in [2].

As mentioned in the introduction, previous studies comparing phonetic categories distinguished by duration have shown that often one category remains virtually unaffected by changes of speaking rate. This result has been attributed by some to the incompressibility of certain categories – such as short-lag VOT – due to strict articulatory limitations, and by others to the need to keep the categories of a linguistic system distinct.

The present results show that to a certain extent both explanations are correct. Specifically, they show that, on the one hand, [ɾ] remains unaffected by changes of rate, precisely as (or even more so than) short-lag VOT does. In contrast, the other single sonorants, whose duration is not so tightly controlled by articulation, are indeed shortened at fast speech rate. This strongly suggests that the stability of certain categories, like [ɾ], is due to their incompressibility, not to constraints imposed by the linguistic system. This interpretation of the results is further supported by the SG sonorants, which did not exhibit greater variation than the CYG sonorants, despite the fact that they could be more variable, since there is no category they could be confused with. In other words, the hypothesis that SG would impose less strict timing on its sonorants was not borne out.

On the other hand, the data also suggest that the linguistic system does exert an influence on the preferred values of particular categories; witness the unusually short durations of the CYG singletons and the longer durations of their SG counterparts. More importantly, perhaps, the influence of the linguistic system is manifested in the fact that the CYG geminates were longer than singletons both within and across speaking rates. In other words, fast rate geminates were not shortened to the extent that they overlapped with singletons spoken at normal rate; the two categories remained clearly apart. This strongly suggests that the results on contrastive vowel length, which show category overlap, are due to the secondary role played by duration in those cases. In contrast, the results here show clearly that when duration is the main cue to a categorial distinction, no overlap occurs between the values of the different categories.

It is fair to say that the results are based only on sonorants, and on one type of contextual change, speech rate. Further research – involving additional parameters and segment types, such as stress and fricatives respectively – will be necessary to consolidate this finding.


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